The frameless membrane: an improved technology for THz circuits

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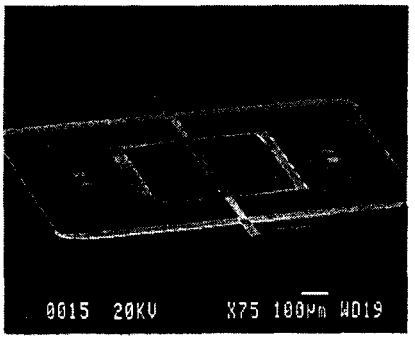
- Chris Mann for Mixer design and assembly

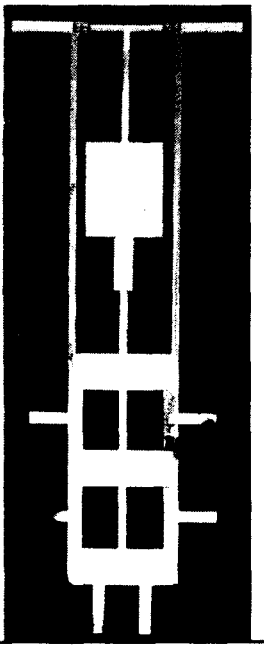
Introduction

- Objectives: build components (mixers, multipliers) with operating frequency in the 1 to 3 THz range.
- Rationale: provide components for space borne receivers.
- State of the Art: Planar Mixers: 2.5 THz (JPL, RAL).
  Planar Multipliers: 600 GHz (JPL).
- Technology development goal: Extend the existing membrane diode (MOMED) technology by:
  - *reducing the thick GaAs support frame to increase design flexibility*
  - *developing new beam lead structures to provide RF probes, tuning elements, mechanical support and DC bias contacts*
  - *implementing multi-diode schemes to expand circuit applications*
  - *shrinking overall circuit dimensions to increase device yield/wafer*
  - *maintaining circuit handleability*
- Status: Built and handled prototype devices. New wafers in process.

Current Technology: Framed membranes



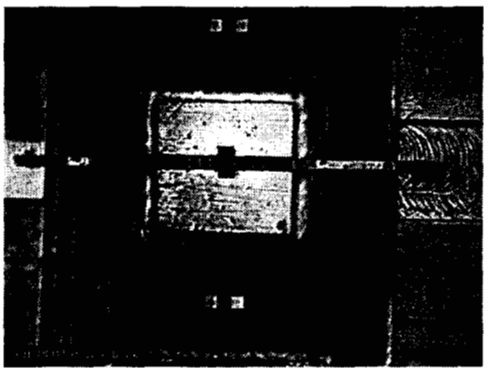
2.5 THz MOMED mixer device



400 GHz sculpted substrate multiplier device

Current Technology: Framed membranes

- Robust.
- Easy handling.
- Planar at very high frequency.



- RF access normal to membrane or through frame.
=> reduced number of implementation and increased loss

Result: Mixer noise temperature 6500K at 2.5 THz: M.Gaidis et al.

Technology: Frameless GaAs Membrane

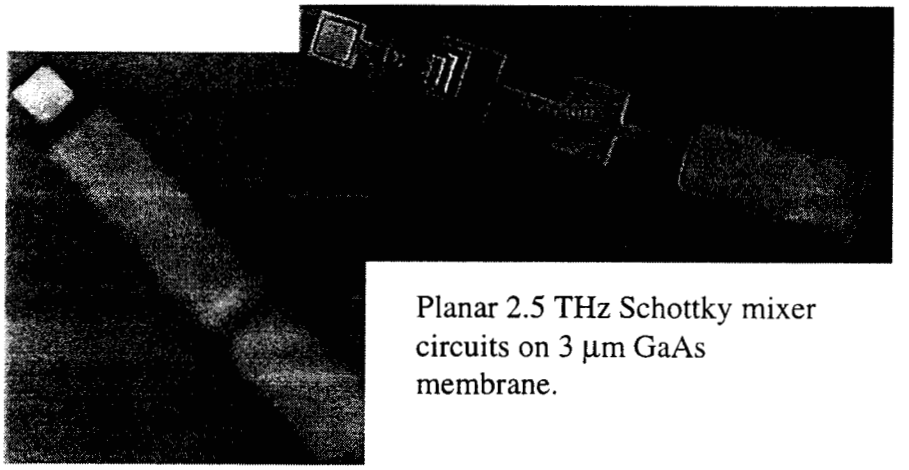
Get rid of frame

- Advantages:
  - Increased design flexibility
  - All shapes possible
  - Split waveguide block implementation possible (no frame in the way)
- Drawbacks:
  - Handling (use of "sacrificial frame" possible)

Extensive use of Beam Leads

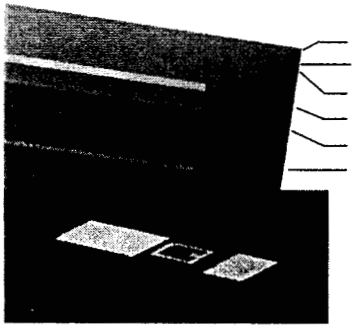
- Advantages:
  - Simplified assembly (no soldering, chip "dropped in")
  - Simplified bias scheme (no wire bonding)
  - Low loss, high bandwidth antennas/circuits (air dielectric)
- Drawbacks:
  - Fragile during handling

Technology:
Frameless GaAs Membrane



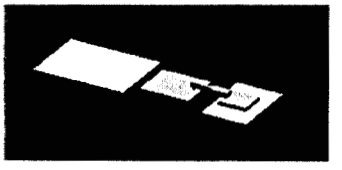
Planar 2.5 THz Schottky mixer circuits on 3 μm GaAs membrane.

Technology:
Frameless GaAs Membrane flowchart

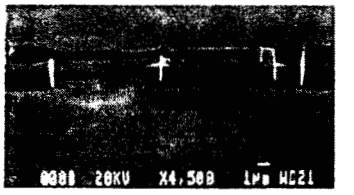


- n^- GaAs
- n^+ GaAs
- AlGaAs etch stop
- i GaAs membrane layer
- AlGaAs etch stop
- SI GaAs

•recessed Ohmic
•Mesa definition
•Interconnect metal

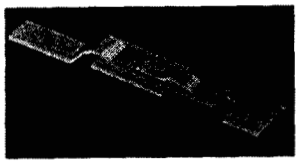


•E-beam anode

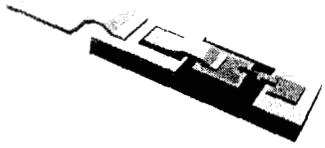


Technology:
Frameless GaAs Membrane flowchart 2

•SiN
•Bridge/capacitor metal



•Membrane definition
•Bridge metal/RF probe/ beam leads

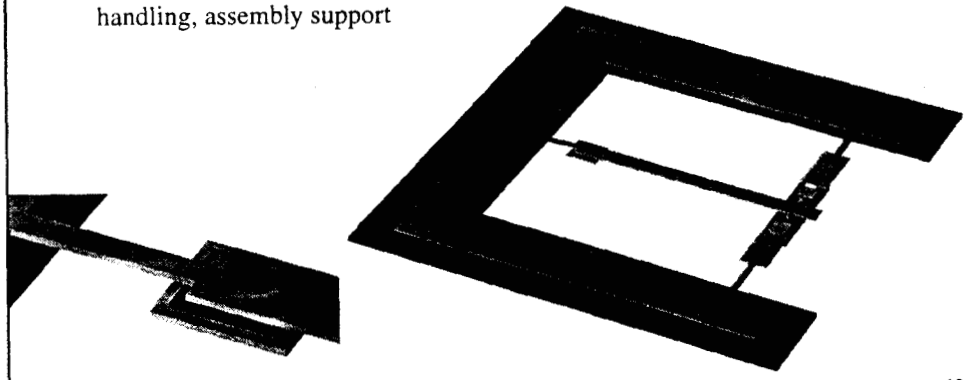


•substrate removed

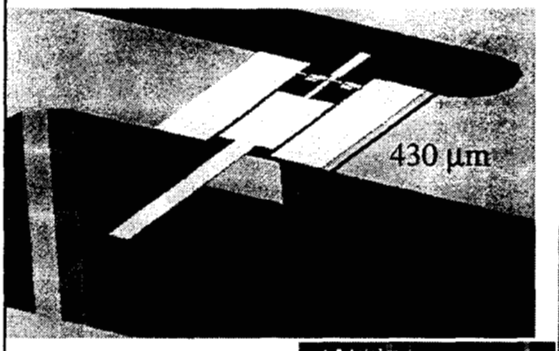
Technology:

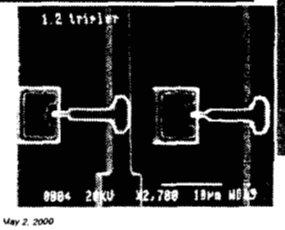
Possible Features:

- Sacrificial handling membrane frame
- Substrateless thin film capacitor (for DC bias isolation)
- Multi purpose beam-leads: RF probes, RF ground/short, DC bias, handling, assembly support



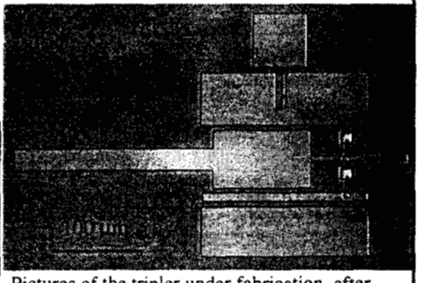
Application: Tripler to 1.2 THz on membrane





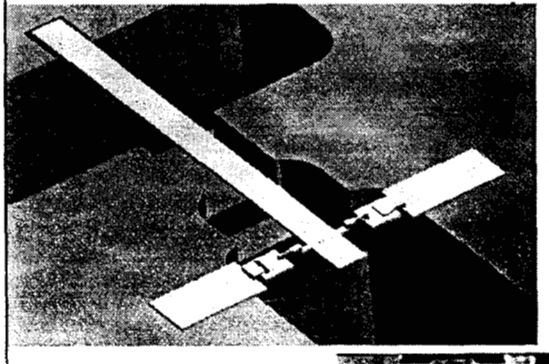
- Balanced tripler for idler tuning.
- Split waveguide block.
- Simple bias scheme.
- Predicted efficiency is 2%.

Planar Diode properties:
Epitaxial doping concentration: 5 X 10^{17} cm^{-3}
Anode dimensions: 1.4 X 3.5 um



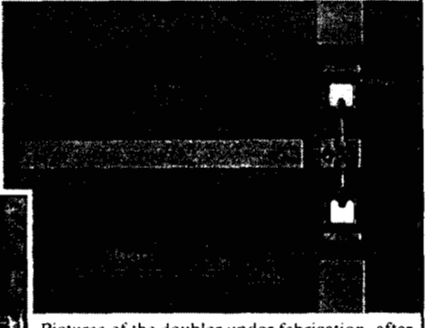
Pictures of the tripler under fabrication, after anode metalization

Application: Doubler to 2.4 THz on membrane



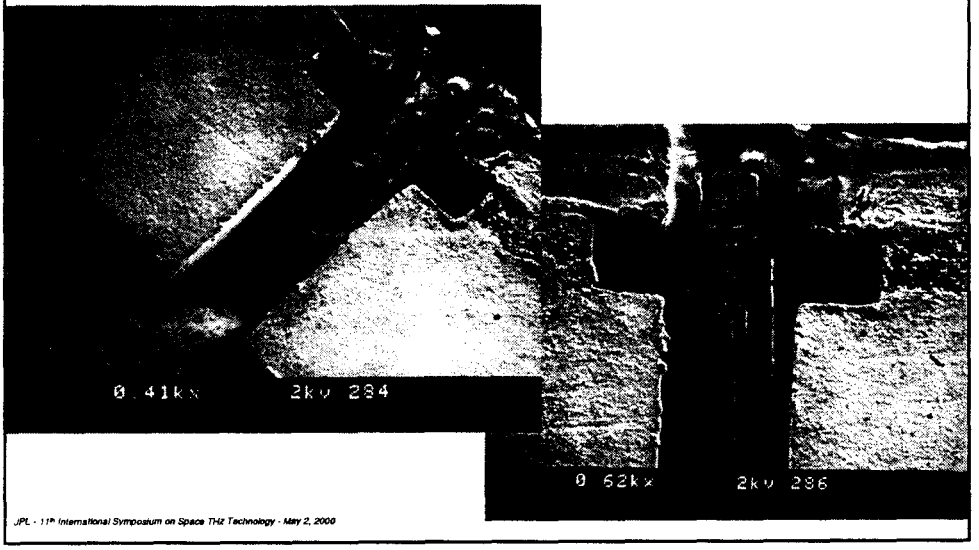
- Balanced doubler for simplified circuit (no filters).
- Split waveguide block.
- Low Power.
- Predicted efficiency is 2.5 %.

Planar Diode properties:
Epitaxial doping concentration: 5 X 10^{17} cm^{-3}
Anode dimensions: 0.14 X 0.6 um



Pictures of the doubler under fabrication, after anode metalization

Application:
2.5 THz mixer (RAL)



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Conclusion

- Frameless GaAs Membrane:
  - Increases design flexibility
    - split waveguide
    - bias scheme
    - integration and assembly
  - More compact structures (more designs/variations per wafer)
- Demonstrated fabrication and handling of prototype.
- High frequency designs to 1200 and 2400 GHz have been completed. The circuits are currently being fabricated.